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JET AZIMUTHAL DECORRELATION STUDIES WITH THE DØ DETECTOR

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For The DØ COLLABORATION

Experimental results on the measurement of the azimuthal decorrelation between jets with pseudorapidity separation up to five units are presented. The data were taken at the Fermi National Accelerator Laboratory during the 1992-1993 collider run with the DØ detector using $p\bar{p}$ collisions at center-of-mass energy $\sqrt{s} = 1.8$ TeV. These results are compared to next-to-leading order (NLO) QCD predictions and to two leading-log approximations (LLA) where the leading terms are resummed to all orders in α_s. The final state jets as predicted by NLO QCD show less azimuthal decorrelation than the data. The parton showering LLA Monte Carlo HERWIG describes the data well; an analytical LLA calculation based on Balitsky-Fadin-Kuraev-Lipatov resummation predicts more decorrelation than is present in the data.

1 Introduction

Perturbative Quantum Chromodynamics (pQCD) has demonstrated good success in describing jet production. Next-to-leading order (NLO) QCD calculations and Monte Carlo simulations using parton shower approaches correctly model many aspects of jet physics [1,2]. However fixed order pQCD is only an approximation of QCD; there are regions of phase space where the approximation fails. This manifests itself in the appearance of large logarithms in the perturbative series. The usual technique of performing a perturbative expansion in powers of α_s no longer works. Such regions as deep inelastic lepton-hadron scattering at small Bjorken x and large Q^2 or hadron-hadron scattering at large partonic center-of-mass energy ($\hat{s}$), need different theoretical treatment than fixed order pQCD. Large terms of the type $ln(\hat{s}/\hat{t})$ have to be resummed, for example using Balitsky-Fadin-Kuraev-Lipatov (BFKL) technique [3]. Since $ln(\hat{s}/\hat{t}) \sim \Delta\eta$ these terms are larger as the rapidity separation between jets become larger, so events with widely separated jets could show more sensitivity to gluon resummation.

Del Duca and Schmidt [4] have used the BFKL theory to resum the leading power of the rapidity interval to all orders in α_s thereby improving the prediction of jet production in the forward region. According to their calculations as $\Delta\eta$ increases $\Delta\phi$ and E_T correlation between the jets are expected to decrease due to intervening gluon emission.

In this study, we select the two jets most widely separated in pseudorapidity ($\eta = -ln[tan(\theta/2)]$, where θ is the polar angle of the jet with respect to the proton beam) , measure the azimuthal correlation of these jets and compare our results to a NLO prediction (JETRAD [5]); a parton shower Monte Carlo including collinear resummation (HERWIG [6]); and the prediction based on BFKL resummation performed by Del Duca and Schmidt.

2 Data Sample and Selection

The data were taken with the DØ detector during the 1992-1993 $p\bar{p}$ collider run at the Fermilab Tevatron. The DØ detector [7] consists of a central tracking system surrounded by a hermetic, finely segmented (0.1×0.1 in $\Delta\eta \times \Delta\phi$) uranium liquid argon sampling calorimeter which is enclosed by the magnetized iron toroids of the muon system. This analysis utilizes the DØ calorimeter system, which is particularly well suited for this measurement, owing to its uniform calorimetric coverage for $|\eta| \leq 4$. The electromagnetic and hadronic resolutions are $15\%/\sqrt{E}$ and $50\%/\sqrt{E}$ respectively, providing good jet energy resolution.

The data for this study represents an integrated luminosity of $137 nb^{-1}$. If an event had greater than 7 GeV transverse energy in a single pseudoprojective calorimeter trigger tower (0.2×0.2 in $\Delta\eta \times \Delta\phi$), it was further analyzed in the online processor farm where a fast version of the jet finding algorithm searched for jets with transverse energy (E_T) greater than 30 GeV.

Offline jet reconstruction was performed using an iterative fixed cone ($R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$) algorithm [8]. The final jet E_T was defined as the

Table 1: Efficiencies and resolutions.

Jet reconstruction efficiency for E_T >20 GeV	> 95%
Jet energy resolution at 50 GeV	10%
Jet position resolution (η and ϕ)	0.03
Jet shape cut efficiency (applied to remove instrumental background)	> 95%
Residual contamination from background (estimated by MC)	< 2%
Pseudorapidity bias	$\delta_\eta \leq 0.03$

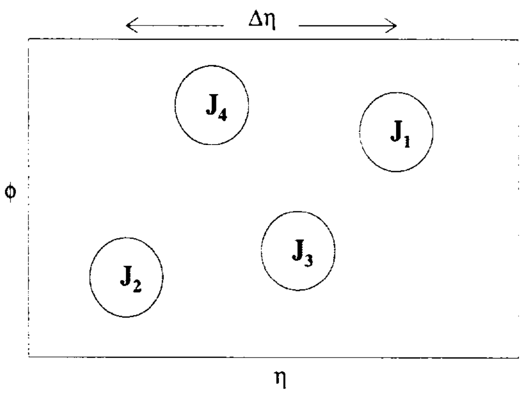

Figure 1: Typical multijet event. Jets are ordered by their η separation.

scalar sum of the E_T of the included towers and its direction was defined using the DØ jet algorithm[8]. The jet E_T was corrected for energy scale, out-of-cone showering, and underlying event [9]. Table 1 summarizes the efficiencies and resolutions relevant to this study.

3 Results

A typical multijet event configuration is shown in Fig. 1. From the sample of jets with $E_T > 20$ GeV and $|\eta| \leq 3.0$, the two jets at the largest rapidity were selected (J_1 and J_2 in Fig. 1) for this analysis. One of these two jets was required to be above 50 GeV in E_T to remove any trigger inefficiency. In Fig. 2, the distribution of the azimuthal angular separation, $1 - \Delta\phi/\pi$ ($\Delta\phi = \phi_1 - \phi_2$), is plotted for unit bins of the pseudorapidity difference ($\Delta\eta = |\eta_1 - \eta_2|$) centered at $\Delta\eta = 1, 3,$

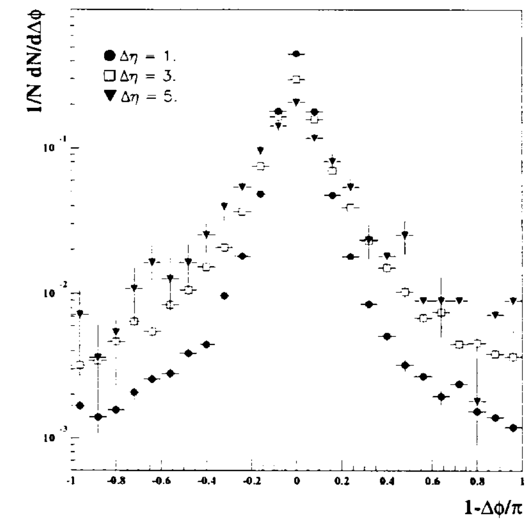

Figure 2: The azimuthal angle difference, $\Delta\phi = \phi_1 - \phi_2$, distribution of the two jets at the extremes of pseudorapidity plotted as $1 - \Delta\phi/\pi$ for $\Delta\eta = 1,3$, and $5(0.5 < \Delta\eta < 1.5, 2.5 < \Delta\eta < 3.5$, and $4.5 < \Delta\eta < 5.5)$. The errors are statistical only.

and 5. Since the distribution is normalized to unit area, the decorrelation between the two most widely separated jets can be seen in either the decline near the peak or the increase in width as $\Delta\eta$ increases.

To quantify the decorrelation, we plot the data in terms of the average value of $cos(\pi - \Delta\phi)$ [10]. Fig. 3 shows $\langle cos(\pi - \Delta\phi)\rangle$ vs. $\Delta\eta$. For the data, the error bars represent the statistical and point-to-point uncorrelated systematic errors added in quadrature. In addition, the band at the bottom of the plot represents the correlated uncertainties of the energy scale and effects due to hadronization and calorimeter resolution. These systematic errors are summarized in Table 2. Also shown in Fig. 3 are the predictions from HERWIG, JETRAD[5], and the BFKL resummation[4,11]. The errors shown for the three QCD predictions are statistical only; however, we estimated the most important uncertainties in the JETRAD predictions as well (see Table 3).

The data in Fig. 3 shows a nearly linear decrease in $\langle cos(\pi - \Delta\phi)\rangle$ with pseudorapidity interval. For small pseudorapidity intervals both JETRAD and HERWIG describe the data reasonably well. JETRAD, which gives only up to three

Table 2: Systematic errors.

$\langle\cos(\pi-\Delta\phi)\rangle$ uncertainties due to Jet energy scale	~ 0.002 @ $\Delta\eta=1$ ~ 0.011 @ $\Delta\eta=5$
Out-of-cone showering	< 0.013
η bias	< 0.002
Jet shape cuts (independent from η and ϕ)	< 0.007
$\langle\cos(\pi-\Delta\phi)\rangle$ uncertainties due to jet finding algorithm	< 0.002
Calorimeter smearing effects	< 0.03 @ $\Delta\eta=5$ < 0.02 @ $\Delta\eta=4$ 0 for $\Delta\eta\leq 3$

Table 3: Uncertainties in JETRAD calculations in terms of $\langle\cos(\pi-\Delta\phi)\rangle$.

Renormalization and factorization scale	< 0.026
Parton distribution functions (CTEQ2M, MRSD, GRV)	< 0.003

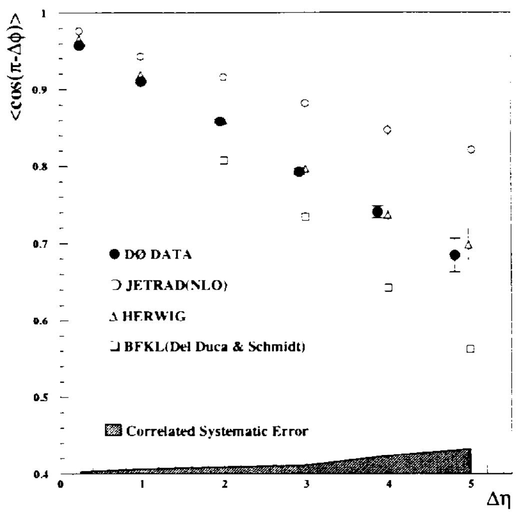

Figure 3: The correlation variable used in this analysis, the average value of $\cos(\pi-\Delta\phi)$ vs $\Delta\eta$, for the data, JETRAD, HERWIG, and BFKL calculations of Del Duca and Schmidt.

final state partons, predicts too little decorrelation at large pseudorapidity intervals. The prediction of the BFKL leading-log approximation, which is valid for large $\alpha_s\Delta\eta$, is shown for $\Delta\eta > 2$. As the pseudorapidity interval increases, this calculation predicts too much decorrelation. Also shown in Fig. 3 is the HERWIG prediction, where higher order effects are modeled with a parton shower. These predictions agree with the data over the entire pseudorapidity range.

4 Conclusions

DØ has made the first measurement of azimuthal decorrelation as a function of pseudorapidity separation in dijet systems. These results have been compared with various QCD predictions. While JETRAD predicts too little and the BFKL resummation predicts too much decorrelation, HERWIG describes the data well over the entire $\Delta\eta$ range.

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